International Journal for Research and Development in Engineering (IJRDE)

www.ijrde.com Vol.2: Issue.2, November-December 2013 pp- 24-28

Cascaded Asymmetric Multilevel Inverter For Wind Energy Conversion System

Rachel Cilvi John[1], P.Sebastian Vindro Jude[2], Dr.R.Mahalaksmi[3]

[1](PG Student, Electrical and Electronics Engineering (PG), Sri Ramakrishna Engineering College, Coimbatore, India Email: richu1989john@gmail.com)

[2] (Asst.Prof. (Sr.G), Electrical and Electronics Engineering (UG), Sri Ramakrishna Engineering College, Coimbatore, India Email: vindro@rediffmail.com)

[3] (Prof. & Head of Department, Electrical and Electronics Engineering (UG), Sri Krishna College Of Technology, Coimbatore, India Email:mahacbe45@yahoo.com)

ABSTRACT

This paper aims on the design and implementation of asymmetric cascaded H-bridge multilevel inverter in the grid side of the wind energy conversion system. The main focus is to design the grid side inverter so as to reduce the total harmonic distortion at the minimum level which is effective on the grid code requirements. The asymmetric cascaded H-bridge multilevel inverter topology has been implemented in this paper to suppress the total harmonic distortion. Thus, the proposed inverter topology is applied in the grid side of the wind energy conversion system to further reduce the total harmonic distortion (THD).

Keywords **–Neutral Point Clamped (NPC), Total Harmonic Distortion (THD), Permanent Magnet Synchronous Generator (PMSG)**

I. INTRODUCTION

Wind power is undergoing the fastest rate of growth than any other form of electricity generation in the world. The low environmental impact of wind energy makes it a very attractive solution. The resource potential is large. Due to the location of these resources and their intermittent nature, issues regarding the resulting impact of the integration of this green energy into the power grid are becoming more and more important. Integration of wing power plant into the electric power system presents challenges primarily due to the natural characteristic of the wind plants – which differ in some respect from the conventional plants.

A typical wind energy conversion system includes a wind turbine, interconnection apparatus, control systems and generators. Wind turbines are mainly categorized as the horizontal axis type or the vertical axis type. Most of the modern wind turbines prefer to use horizontal axis configuration with two or three blades, operating either down-wind or up-wind over vertical axis type machines. A wind turbine can be designed for a variable speed operation or constant speed operation. Variable speed wind turbines are capable of producing 9% to 15% more energy output as compared to their constant speed. But it necessitates the need for power electronic converters to provide a fixed frequency and fixed voltage power to their loads. Recently many of the turbine manufactures have opted for reducing gears between the low speed turbine rotor and the high speed three-phase generators. In direct drive configuration, a generator is directly coupled to the rotor of a wind turbine. The main idea behind this is that it offers low maintenance, high reliability, and low cost. Hence many manufacturers have opted for the direct drive configuration for designing turbines in the recent years.

At the present time and in the near future, the wind turbine generators would be synchronous generators, induction generators, permanent magnet synchronous generators, and the squirrel cage type and wound rotor type. For small to medium power applications the wind turbine generator would be permanent magnet generators and squirrel cage induction generators. These are often preferred because of their reliability and cost advantages. For high power applications, wind turbines uses induction generators, wound field synchronous generators and permanent magnet synchronous generators. The wind turbines are also applied with both voltage source voltage controlled inverters and voltage source current controlled inverters. The effective power control for certain high power wind turbines can be achieved by the use of a double PWM (pulse width modulation) converters which provide a bi directional power flow between the turbine generator and the utility grid. [1]

Recently, industries are showing an increasing demand in power equipment, which have now reached to megawatt level. Today, it has become hard to connect a single power semiconductor switch directly to medium voltage grids (2.3, 3.3, 4.16, or 6.9 kV). Due to these reasons, new families of multilevel inverters are being emerging as the solution for working with higher voltage levels. Multilevel inverters are basically an array of power semiconductors and capacitor voltage sources. The output of multilevel inverter generates voltages with stepped waveforms. The most attractive features of multilevel inverters are as follows.

1) They are capable of generating output voltages with extremely low distortion and lower $\frac{dv}{dt}$.
2) They can take in input current with very low distortion.
3) They only generate smaller common-mode (CM) voltage, as a result of which the stress in the motor bearings gets reduced.
4) They operate with a very lower switching frequency [2]

II. OVERVIEW OF THE SYSTEM

The block representation of the proposed system is as shown in the Fig 1 with modification in the inverter part.

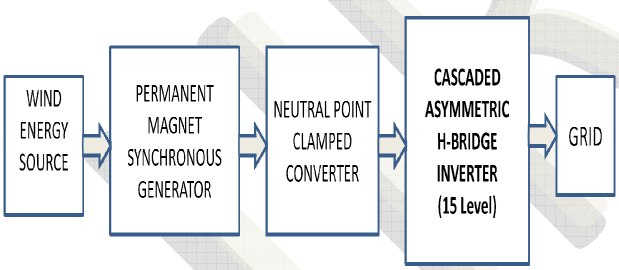

Figure 1: General Block Diagram

2.1 Wind Energy Source

The energy from the wind can be harnessed by wind turbines to generate electricity. Modern wind turbines generate electricity typically around 80% of the time. The variation in the output from wind energy depends on wind speed. But over the course of a period, a turbine is designed with a point to generate almost 30% of its theoretical maximum output. This ability of the wind turbine is known as its capacity factor. The capacity factor by which conventional power plants are designed is typically around 50%. As we all know the wind does not blow always due to many environmental factors. During one point of time, one region may be calm while another one may be windy. Hence, the overall fluctuations in wind blow can be significantly reduced if wind turbines are spread out across a country or region. Wind turbines tend to generate more power during the day when it is needed most and less at night, a pattern that corresponds well to the electricity demand. The energy that is available in the wind is cubically related to the speed at which it is moving.

2.2 Permanent Magnet Synchronous Generator

A Permanent magnet synchronous generator is a generator in which the excitation field is provided by a permanent magnet in turn of a coil. The synchronous generators are the main source for the generation of commercial electrical energy. They are mainly used to convert the mechanical output power of gas turbines, hydro turbines, steam turbines, wind turbines and reciprocating engines into electrical power required for the grid. They are all known as synchronous generators as the rotor speed must always match with the supply frequency. In a permanent magnet generator, the rotor magnetic field is always produced by permanent magnets. Other types of generator make use of electromagnets to produce a magnetic field in the windings of the rotor. The direct current in the rotor field winding is fed through a slip-ring assembly or provided by a brushless exciter on the same shaft. The main advantage of permanent magnet generators is that it does not require a DC supply neither in the circuit for excitation, nor there is the need of slip rings and contact brushes. But, large permanent magnets are more expensive which is the primary reason for restricting the use of it in the economic ratings of a machine. Also the high performance permanent magnets have limited flux density. The air gap flux is also not controllable; hence the voltage of the machine cannot be regulated easily. A persistent magnetic field results in safety issues during assembly, service and repair. High performance permanent magnets, themselves, have thermal and structural issues. Torque current MMF vector- ally combines with the persistent flux of permanent magnets, which results in higher air-gap flux density and ends in the saturation of the core.

2.3 Generator Side Converter

A generator side converter connected to the stator of the PMSG effectively decouples the generator from the

network. Thus, the wind turbine rotor and the generator can rotate freely depending on the conditions of the wind. Generally Park's transformation is used for transformation into reference frame. As the converter is directly coupled to the PMSG, its q-axis current is proportional to that of the active power. The active power reference P, is determined in such a way that it can provide maximum power to the grid. But when a network disturbance occurs, the terminal voltage at the high voltage side of the transformer, Vgrid decreases. Therefore, in such a case, it is appreciable not to keep the active power reference set point at the maximum power level. This is done in order to avoid the over voltage of dc-link. The three level neutral point clamped converter has shown in the Fig 2. On the other hand, the d-axis stator current is proportional to the reactive power. The reference value of the reactive power is set to zero to have an unity power factor operation. For both the converter and inverter, the carrier signal used is triangular wave for PWM operations.[3] The carrier frequency is chosen to be 1000 Hz for converter and 1050 Hz for inverter, respectively.

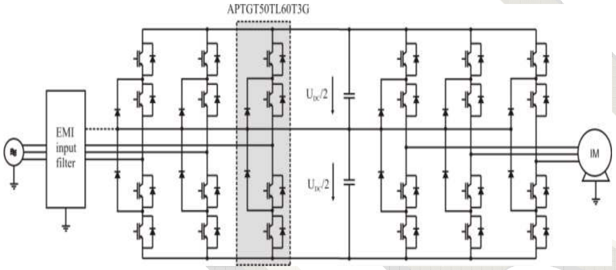

Figure 2 Three Level Neutral Point Clamped Converter

Nowadays, renewable energy systems are undergoing an important development. Among them wind energy stands out for its installed capacity, power generation and steady growth. Due to the expected rated power growth of the wind turbines, the high power converter topologies acquire an increasing interest. Multilevel converters are particularly useful for power values above 2-3 MW. Among the different multilevel converters topologies the three-level neutral-point clamped (NPC) converter is the most widely used. The three-level NPC converter in addition gives some more improvements over the standard two level converters, which are being most commonly used in wind energy applications. One among them is that the DC-link capacitor and the power devices need to withstand only one half of the DC-link voltage, as such the converter can have double voltage and power values. Another one is regarding the spectrum of the output voltage which is better than the one from the standard two-level converter, which ensures the reduction of the reactive components, such as the inductors needed for a grid-connected converter.

2.4 Generator Side Inverter

The aim of the grid side inverter control is to keep the dc link voltage constant, thereby insuring that the active power generated by the generator is fed back to the network. In addition, they are also capable in controlling the reactive power which is fed back to the grid.[3] The selection of an adequate multilevel topology to supply a specific load has been addressed by several researchers. As the number of level increases in a multilevel inverter so does the output gets improved with minimizing the harmonic contents and distortions.

Asymmetric multilevel inverters have the same topology as symmetric ones; the only difference is in the dc link voltages. Since the different cells of asymmetric inverter work with different dc link voltages and different switching frequencies, it is more efficient to use appropriate semiconductor devices in different cells. A hybrid inverter which uses several types of semiconductors has many advantages. Active power is transferred by semiconductors with low losses and high reliability and the output harmonic spectrum is improved by other semiconductors. The inverter consists of a main cell with IGCT switches and a sub cell with IGBT (Insulated-Gate Bipolar Transistor) switches. Main and sub cells are connected in series in each phase. IGCT is a device with high reverse voltage, high reliability and low losses which is used in the main cell, while IGBT is a device with high switching frequency which is used in the sub cell to obtain low harmonic spectrum in the output of inverter.

The type of configuration used here can be called 1-2-4, and it receives this name because the voltage amplitude of the input dc voltage source that supplies cell 2 is twice the dc voltage amplitude of cell 1 and the voltage amplitude of the input dc voltage source that supplies cell 3 is four times the dc voltage amplitude of cell 1 . The dc voltage source of cell 1 is 33V, while the dc voltage source of cell 2 is 66V and of cell 3 is 132V. Multilevel inverters are designed to present 99% efficiency at the nominal operating point.

2.4.1 Total Harmonic Distortion

The THD of a signal is the ratio of the sum of the powers of all harmonic frequencies above the fundamental frequency to the power of the fundamental frequency, and it can be obtained by

$$THD\ \% = \frac{100}{U_1}\sqrt{\sum_{h=2}^{\infty} U_h^{\,2}} \quad \text{------------ (1)}$$

Where,

U_1 is the first harmonic of the signal analyzed,
h is the harmonic order,
U_h is the harmonic that presents order h.

The hybrid multilevel modulation technique is used to guarantee that some cells operate at low frequency and only one cell operates at high frequency. This strategy associates the stepped voltage waveform synthesis in higher power cells with high-frequency PWM for the lowest power cell. Based on the models for each device, the conduction and switching power losses are calculated for each semiconductor. The sum of all losses is computed to obtain the total power losses.

III. SIMULATION RESULTS

For the simulation of the wind energy conversion system, initially PMSG and the converter unit with the wind source is recorded and it is connected to the cascaded H-bridge multilevel inverter which has the sinusoidal pulse width modulation as input for its subsystem. Then the total harmonic distortion percentage is been measured through FFT analysis. The simulation result of the 15 level cascaded asymmetric multilevel inverter is as shown below in Fig 3.

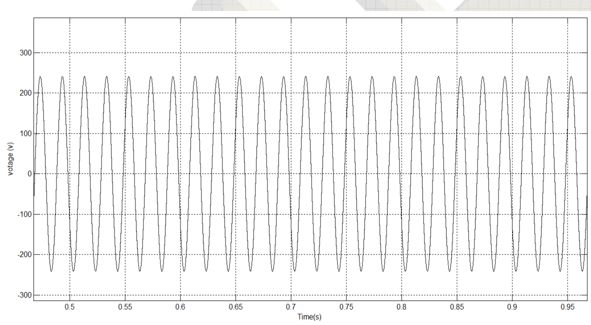

Figure 3: 15 Level Output Waveform from H- Bridge

The simulation result of FFT analysis to obtain the total harmonic distortion of the cascaded multilevel inverter is as in Fig 4.

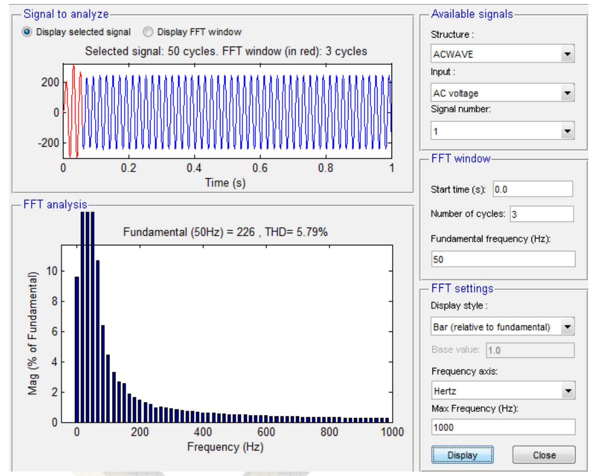

Figure 4: Result of FFT analysis

IV. CONCLUSION

Thus the asymmetric cascaded H-bridge multilevel inverter has developed and simulated using MATLAB and the results has been recorded. The simulated result shows that the total harmonic distortion in the grid side inverter has been reduced to 5.79% and hence it can be effectively used in the wind energy conversion system.

The proposed method concentrates on the grid side inverter to reduce the total harmonic distortion for wind energy system. In order to further enhance the performance other converter topology can be used in the generator side. Also the combination of these generator side converter and asymmetric cascaded H-bridge inverter can be tested for further improvement. Developing a hybrid system can also be taken into consideration.

REFERENCES

[1] Rajveer Mittal, K.S.Sandhu and D.K.Jain, "Overview of Some Important Issues Related to Wind Energy Conversion System (WECS)", *International Journal of Environmental Science and Development, Vol. 1, No. 4, pp. 351- 363, October 2010 ISSN: 2010-0264*

[2] José Rodríguez,, Jih-Sheng Lai,and Fang Zheng Peng, "Multilevel Inverters: A Survey of Topologies, Controls, and Applications", *IEEE Transactions On Industrial Electronics, Vol. 49, No. 4, pp. 724 – 738, August 2002.*

[3] Muyeen.S.M, Rion Takahashi, Mohd. HasanAli, Toshiaki Murata, and Junji Tamura(2010), "A Variable Speed Wind Turbine Control Strategy to Meet Wind Farm Grid Code Requirements", *IEEE Transactions on Power Systems,Vol. 25, No. 1, pp.331-340*

[4] RionTakahashi,Muyeen.S.M,,Mohd.HasanAli,Toshiaki Murata, and JunjiTamura (2008),"Transient Stability Augmentation of Power System Including Wind Farms by Using ECS", *IEEE Transactions On Power Systems, Vol. 23, No. 3, pp.1179-1187*

[5] Salman.S.K and Teo.A.L.J, "Windmill Modeling consideration and factors influencing the Stability of a Grid-connected Wind Powerbased Embedded Generator," *IEEE Transactions on Power System, Vol. 18, No. 2,pp. 793–802*

[6] Sharad W. Mohod and Mohan V. Aware, "A STATCOM-Control Scheme for Grid Connected Wind Energy System for Power Quality Improvement", *IEEE systems journal, Vol. 4, No. 3, pp.346-358*

[7] TatsutoKinjo,TomonobuSenjyu,NaomitsuUrasaki,and Hideki Fujita, "Output Levelling of Renewable Energy by Electric Double-Layer Capacitor Applied for Energy Storage System", *IEEE Transactions On Energy Conversion, Vol. 21, No. 1, pp.221-227*